The Role of Evapotranspiration Models in Irrigation Scheduling

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ABSTRACT

MOST evapotranspiration (ET) models are based on physical principles controlling evaporation and the conservation of mass and energy, and use daily climatic data. ET models coupled with irrigation models are valuable tools because they enable trained and experienced irrigation specialists to provide irrigation scheduling services at a reasonable cost.

Estimated standard deviations of mean daily ET for 1- to 30-day periods ($S_{\overline{et}}$) at Akron, Colorado; Davis, California; Kimberly, Idaho; and Lompoc, CA varied from 0.9 to 1.3 mm/day. $S_{\overline{et}}$ decreased to 0.4 to 0.7 mm/day for 15- to 30-day periods.

Standard errors of ET estimates ($S_{y.x}$) with a combination equation based on 243 days of data from Kimberly, ID were normally distributed. The $S_{y.x}$ for daily values was 1.0 mm/day. The $S_{y.x}$ decreased inversely with the square root of the number of days for up to 30 days and was similar to those reported for other areas using models that operate on daily climatic data.

A summary of factors affecting confidence levels in irrigation scheduling is presented along with the expected standard deviations. Generally, the error in estimating irrigation applications exceeds estimated ET errors. The error in measuring soil moisture is generally smaller than estimated ET and irrigation application errors.

INTRODUCTION

Irrigation scheduling with computers has continued to expand following release of the USDA-ARS computer program (Jensen, et al. 1970, 1971). In 1974, about 155,000 ha (350,000 acre) were scheduled and monitored at 1- to 2-week intervals on a field-by-field basis by commercial and agency service groups (Jensen, 1975). Between 1974 and 1976, seven commercial groups added about 2,000 fields and 69,000 ha (170,000 acre), and the total area served on a field-by-field basis was over 243,000 ha (600,000 acre). Most service groups estimate soil water depletion and project irrigation dates using current climatic data. Estimated soil water depletion can be adjusted after monitoring each field. Monitoring practices depend on the crop, soil, and experience of field technicians.

Common problems encountered by service groups involve soil variability, determining previous irrigation dates and amounts, and adapting experimentally derived general crop coefficients to specific conditions in each field. Some problems are associated with limited training and experience of personnel operating the scheduling program and technicians monitoring the fields.

The computer scheduling program is a valuable tool for irrigation specialists, but many service groups expect too much from scheduling programs. Some users do not know which parameters or variables to adjust to fit a program to field conditions.

This paper was prepared in response to problems encountered with irrigation scheduling. It also assesses the role of evapotranspiration (ET) models in scheduling irrigations.

ET MODELS ARE NEEDED

Irrigation is only one of many farm operations that must be scheduled; therefore, estimates of when to irrigate that are within ± 2 to 3 days for 20- to 30-day frequencies are considered adequate (Jensen, et al., 1971).

Irrigation scheduling involves estimating the earliest date to permit an efficient irrigation, and the latest date to avoid economic adverse effects on the crop. Within this time period, farm managers plan their irrigations for the next 5 to 10 days to complete cultivations, crop spraying, and other needed cultural practices. Irrigation scheduling also involves estimating the amount of water to be applied. In many cases, the amount applied may be predetermined by the irrigation system. For example, with sprinkler systems, either 7- to 8- or 11- to 12-h sets may be used. The date of the next irrigation should permit sufficient soil moisture to be depleted so that the water applied can be retained. Some managers avoid full irrigations to permit retaining expected precipitation. Surface irrigation systems typically are operated for fixed time periods, but the amount of water applied depends on both the irrigation duration and the soil's intake capacity, which may change significantly during the growing season. In arid areas, many managers rely on past experience and tend to irrigate at fixed time intervals. This practice can result in efficient irrigations when crops are planted about the same time each year and the soil water level is either at field capacity or at about the same level of depletion at planting. Such schedules also can be very inefficient, however, if irrigations are regularly applied too soon. Unintentional delays in irrigations followed by excessive irrigation are common and are both inefficient and may reduce crop yield and quality.

Most farmers know the current soil water level in

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the plow layer, but very few regularly evaluate the soil water level at greater depths. As a result in some years yields may be severely affected because of delayed irrigations and in other years excessive irrigations early in the season may leach valuable nitrate nitrogen and cause expensive drainage problems.

Many farmers also know about how much water is removed daily from their fields by ET. However, we have observed that very few farmers utilize available average ET data to plan and schedule their irrigations. The main reason appears to be the time required for routine book work and monitoring the available soil water level in each field. In Idaho, the Extension Service and U.S. Bureau of Reclamation began publishing estimated current ET for major crops several times each week in 1976. This information is influencing irrigation scheduling.

Some service groups use existing average ET data to provide estimates of the soil water status to farmers. These groups take gravimetric soil samples periodically or use the "feel method" to determine the soil water content and recommend the time and amount of next irrigation. The principal function of a scheduling program is to aid service groups in performing routine calculations of estimated soil water depletion and projected irrigation dates for a large number of farm managers. A scheduling program is a tool that increases the ability of irrigation specialists to provide irrigation scheduling services. A computer program that has one or more models to simulate plant growth and ET does not make untrained and inexperienced personnel instant experts. But, scheduling programs have become valuable educational tools for irrigation specialists in understanding the ET process. Farm managers receiving current estimates of ET rates and the soil water status by fields have increased their understanding of the soil-plant-atmosphere system without special training.

One of the more common problems encountered by inexperienced personnel attempting to begin scheduling services is the inflexibility of on-farm irrigation systems and current water delivery policies. Service groups must be aware of farm management's ability to respond to recommended changes in irrigation practices and the constraints of existing water delivery policies. Some groups just beginning an irrigation scheduling service also do not recognize limitations of ET models in accounting for various factors affecting the current soil water depletion. Others have attempted to develop much more accurate estimates of soil water depletion than that required.

The material presented in the next section describes the expected confidence limits for estimating soil water depletion using simple or complex ET models, and other factors that create greater uncertainty in projected irrigation dates and amounts.

EXPECTED EVAPOTRANSPIRATION RATES

Mean ET rates derived experimentally for various crops in similar climatic areas when combined with measured precipitation and estimates of runoff and deep percolation, can provide excellent guides for irrigation scheduling, as demonstrated by Brosz, et al. (1975). The deviation from the expected mean ET rate during any time period can be estimated from the standard deviation of these rates.

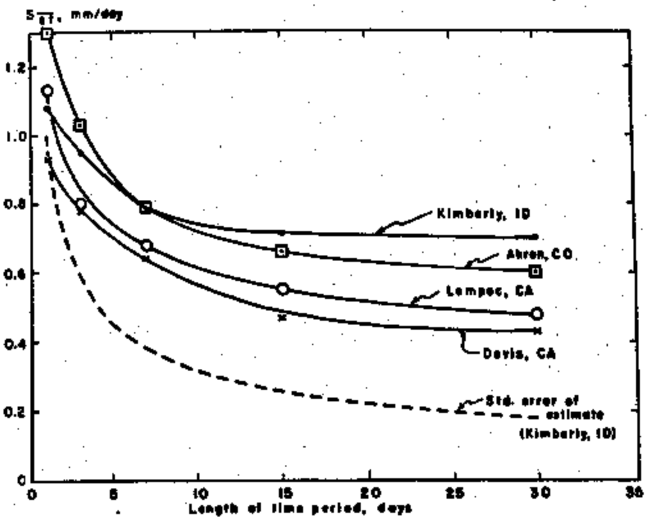

FIG. 1 Estimated standard deviation of evapotranspiration during the peak periods at Davis, CA [Pruitt, et al. 1972], Lompoc, CA [Nixon, et al. 1972], southern Idaho [Wright and Jensen, 1972], and in eastern Colorado [Heermann, et al., 1974].

The standard deviation of expected mean ET rates for crops like grass or alfalfa during peak water use periods, estimated from several recent publications, appears to be normally distributed. Therefore a normal distribution was assumed $(2S = (\bar{x} + S) - (\bar{x} - S))$ with S = one standard deviation, and standard deviations of mean ET rates were estimated using equation [1].

$$S_{\overline{ET}} = \frac{E_1 - E_2}{2} \quad \text{[1]}$$

where $E_1 = \bar{x} + S$ or the 84 percent probability ET rate, $E_2 = \bar{x} - S$ or the 16 percent rate, and $S_{\overline{ET}}$ = the estimated standard deviation of the mean ET rates in mm/day for time periods of 1 to 30 days.

According to results plotted in Fig. 1, the estimated standard deviation of daily ET ranges from 0.9 to 1.3 mm/day. The estimated standard deviation of mean ET rates for 7- to 10-day periods decreases to 0.6 to 0.8 mm/day and for 15- to 30-day periods to 0.4 to 0.7 mm/day. Therefore, if the expected mean ET rates are used to estimate future irrigation dates, the standard error of these estimates for 10 day periods will be less than 8 mm. Thus, two-thirds of the time if mean ET rates are used to estimate ET for 10-day periods, the projected irrigation dates will be accurate within ± 1 day for periods with no rain when mean ET rates are 6 to 8 mm/day.

ACCURACY OF ET ESTIMATES

The estimated standard error of ET estimates ($S_{y.x}$) for Kimberly, ID for daily and 3- to 30-day independent periods was calculated as the standard deviation of the difference between estimated ET (y) using U.S. Weather Service data and measured ET (x) using weighing lysimeters $(S_{y.x} = \sqrt{\Sigma(x-y)^2/(n-1)})$.

Data for 243 days from 1968 through 1971 for periods when the lysimeter and surrounding field had a full

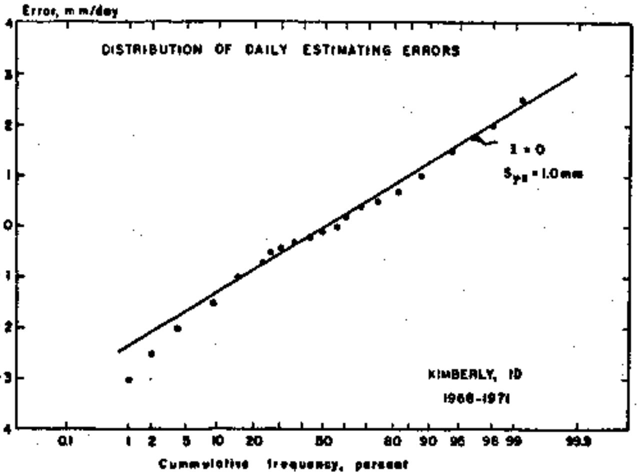

FIG. 2 Distribution of daily errors in estimated ET compared with measured ET for alfalfa at Kimberly, ID, 1968-1971.

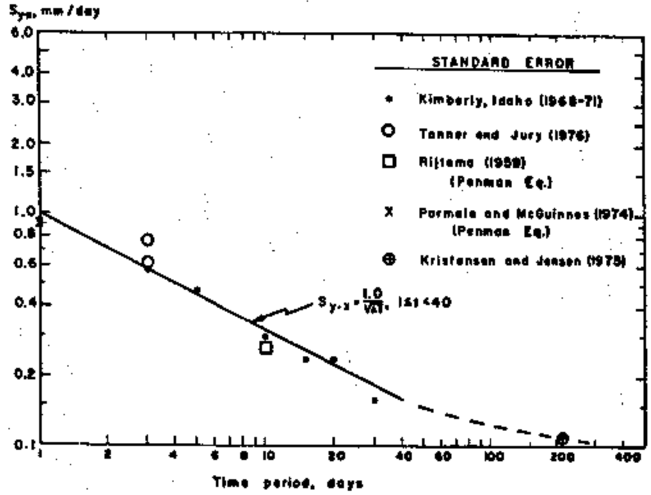

FIG. 3 Estimated standard error in estimating evapotranspiration at Kimberly, ID, compared with estimates of other areas.

cover of alfalfa and were well watered were used.

ET was estimated with a combination equation described by Wright and Jensen (1972) which requires daily net radiation, windspeed, mean vapor saturation deficit, and air temperature. Net radiation was estimated from solar radiation, windspeed was from the Kimberly U.S. Weather Service anemometer located 3.66 m above ground, and dew point was based on humidity measured at 0800 h at the same site. Mean saturation vapor pressure was the mean of the saturation vapor pressure at the maximum and minimum air temperatures.

The daily estimating errors were essentially normally distributed, except for about 5 percent of the low estimates as shown in Fig. 2. The standard errors for the estimated 3- to 30-day mean ET rates decreased inversely with the square root of the respective time period as shown in Fig. 3. Therefore the standard error for a period can be estimated from the standard deviation of daily ET from the mean $(s_{\bar{x}} = s/\sqrt{n})$.

The data presented in Fig. 3 also indicate that the standard error in estimating daily ET with ET models and daily climatic data is about 1 mm/day. Tanner and Pelton (1960) reported a standard error of ~~0.84~~ 0,81 mm/day with the Penman equation in Wisconsin. The standard error in estimating ET for Kimberly decreased to 0.5 mm/day for 4-day periods, 0.33 mm/day for 9-day periods, and 0.2 mm/day for 25-day periods, which is about one-half of the expected standard deviation of mean ET for comparable periods. Similar results were obtainable with either a combination equation calibrated for an area, or a calibrated equilibrium equation (Priestley and Taylor, 1972) in Wisconsin, Ohio and Denmark.

The regression equation for the estimated standard error of ET estimates shown in Fig. 3 is plotted as a dashed line in Fig. 1 to illustrate that for single days, estimates of daily ET using climatic data may be only slightly better than using the expected daily ET for a location. However, for time periods greater than one day, ET models greatly improve the accuracy of ET estimates when compared with using the expected mean daily ET.

The standard error in estimating ET does not seem to be related to the magnitude of ET, although we had only limited data during periods of very low ET. Estimates of daily ET may be improved using the Bowen ratio and energy balance methodology, but this requires continuous measurements of net radiation and humidity and air temperature gradients over the crop. For example, Fritschen (1965) reported 13 selected days of ET measured with the Bowen ratio method and lysimeters in Arizona in 1963 and 1964. The estimated standard error of the ET determined by the Bowen ratio-energy balance method compared with the lysimeter ET was 0.63 mm/day using daily totals and 0.35 mm/day using only daytime totals. Similarly, Parmele and Jacoby (1975) reported 7 days of Bowen ratio data and corresponding lysimeter data with an estimated standard error of 0.17 mm/day. Thus the standard error may be reduced by using the Bowen ratio technique, but the method is much more complicated and expensive than using daily climatic data. For scheduling purposes, the increased accuracy probably would not justify the increased cost and reduced reliability due to a greater probability of instrument failure when operated continuously during the entire growing season.

IRRIGATION CONFIDENCE LEVELS

The principal factors affecting the confidence levels of predicted irrigations include probable errors in estimating ET, the amount of irrigation water applied, drainage from the root zone, upward flow from a capillary fringe, and effective rainfall. Estimated magnitudes of uncertainty of various components affecting soil water depletion illustrate the need to monitor soil water depletion to adjust or tune the estimated soil water depletion to observed conditions. Monitoring soil water depletion may not be required during the entire growing season if an excess amount is applied at each irrigation or if the amount of irrigation water applied and rainfall are known with reasonable accuracy. For example, Heermann, et al. (1976) reported that the USDA-ARS scheduling program calibrated for the eastern Colorado area satisfactorily predicted soil water depletion without adjustment during several cropping seasons.

The standard error in estimating soil water depletion (D) and the contribution of the various components that are summed ($m = m_1 + \ldots + m_n$) can be approximated assuming that the individual components are independent and normally distributed random variables,

$$(\sigma = \sqrt{\sigma_1^2 + \ldots + \sigma_n^2}).$$

$$S_D = \sqrt{S_{\overline{et}}^2 + S_{(I-d)}^2 + S_R^2 + S_u^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad [2]$$

where S_D is the estimated standard error of the estimated soil water depletion, $S_{\overline{et}} = (\Delta t)S_{y.x}$ = the standard error in estimating $\overline{ET}$ over the time period Δt since the last reference value (measured soil water depletion or field capacity following a full irrigation when D = 0), $S_{(I-d)}$ = the standard error in estimating the net amount of water applied for each irrigation or irrigation (I) minus internal drainage (d), S_R = the standard error in the measured or estimated rainfall that penetrated the soil, and S_u is the standard error in the estimated flow into the root zone from a capillary fringe.

Gravimetric soil sampling has been used for predicting irrigation dates on research plots and fields for over half a century. Several commercial service groups use gravimetric procedures to monitor the soil water content and predict irrigation dates using mean expected ET. During the past decade, neutron probes have been used largely for soil water measurements in research but they are used to a limited extent to monitor fields and schedule irrigations commercially (Gear, et al. 1976).

The standard error in estimating soil water content from gravimetric samples varies with soil characteristics. For example, Staple and Lehane (1962) found that the standard deviations for gravimetrically determined soil water for a 1.2-m profile ranged from 15 to 32 mm. Taylor (1955) estimated a coefficient of variability ($100\ S/\sqrt{x}$) of about 10 percent for field sampling. These standard deviations included natural variations within the field.

The standard error in estimating the depletion of soil water is normally less with the neutron probe because a larger soil volume is sampled and the water content is measured on a volume basis at the same sites within the field. The standard error in measuring soil moisture with a neutron probe reported by Bowman and King (1965) ranged from 0.1 percent by volume at low moisture levels to 0.25 percent at high levels, or from 1.3 to 3.3 mm for a 1.3 m-profile. van Bavel (1963) conservatively estimated the absolute accuracy of the neutron method to about 0.5 to 1 percent moisture by volume, or 5 to 10 mm/m of soil.

The objective of periodically monitoring soil water for irrigation scheduling purposes is not to determine the absolute soil water content in a field, but to determine the depletion from effective field capacity (Jensen, 1972). This is much easier than sampling adequately to determine the average absolute water content. For example, if a field contains some soil with an available water-holding capacity of 150 mm/m and some with 200 mm/m, the irrigation objective may be to irrigate the entire field before about 100 to 120 mm of available soil water have been depleted. Thus, fewer monitoring sites, if carefully selected to represent the major soil type and crop growth characteristics, are needed to determine the soil water depletion compared with estimating absolute quantities. The standard deviation of soil water depletion from a 0.75-m depth of Portneuf silt loam in southern Idaho on which sugarbeets were grown was evaluated for 6 irrigation intervals using 8 neutron sites. Irrigations were made in alternate furrows spaced 60 cm apart and the furrows irrigated were alternated each irrigation. The estimated standard deviation of soil water depletion averaged 7 mm on plots irrigated for 24 h and averaged 11 mm on plots irrigated for only 12 h. The higher deviation on plots irrigated for 12 h occurred because these plots did not reach effective field capacity after each irrigation during the summer months. These results agree with expected values suggested by van Bavel (1963). Therefore, since soil water monitoring with the neutron probe probably would be limited to the top meter of soil, the standard error in measured soil water depletion per neutron probe site (S_Θ) could be approximated using S_Θ = 5 mm following full irrigations and S_Θ = 10 mm on furrow-irrigated and other fields that may not receive full irrigations.

TABLE 1. STANDARD ERROR OF THE ESTIMATED MEAN DEPTH OF WATER APPLIED WITH SPRINKLER SYSTEMS VERSUS THE UNIFORMITY OF APPLICATION AND THE NUMBER OF GAGES USED.

		S_I if measured with the following number of gages‡			
U_c*	s†	2	4	8	16
100	0	0	0	0	0
95	6.3	4.4	3.1	2.2	1.6
90	12.5	8.8	6.3	4.4	3.1
85	18.8	13.3	9.4	6.6	4.7
80	25.0	17.7	12.5	8.8	6.3
75	31.3	22.1	15.6	11.1	7.8
70	37.5	26.5	18.8	13.3	9.4

*Christiansen's uniformity coefficient, $U_c = 100\,(1.0 - \Sigma|x - \bar{x}|/N\bar{x})$

†For $U_c > 70$ percent, $U_c \approx 100\left(1 - \frac{0.8s}{\bar{x}}\right)$, (Hart and Reynolds, 1965), and assuming $\bar{x}$ = 100 percent.

‡$S_I = s/\sqrt{n}$, where n is the number of randomly spaced rain gages used.

The greatest uncertainty in estimating soil water depletion is associated with the net irrigation (I-d) applied on surface-irrigated fields, except when excess irrigation water is applied. Overirrigation is common on many surface-irrigated fields. On the Idaho plots irrigated for 24 h, the standard deviation of the net irrigation amount for 6 irrigations ranged from 6 to 19 mm. The smallest value occurred late in the season when ET rates were low. These results indicate that the standard error of (I-d) may be approximated by using $S_{(I-d)}$ = 15 mm where full irrigations ($D \cong 0$) are applied with furrows. This may be less for basin irrigation. With partial irrigations on medium textured soils $S_{(I-d)}$ could be approximated as 30 mm.

With sprinkler systems, the average amount of water applied can be estimated based on nozzle sizes, sprinkler spacings, and operating pressures. Also, the mean irrigation depth can be estimated from measurements of the amount applied using several cans or rain gages. The number of gages needed depends on the expected uniformity coefficient and desired accuracy, as shown in Table 1. With center pivot systems, the irrigation depth remains relatively constant for each rotation once the mean depth has been determined.

If water is measured into level basins the standard deviation of the amount delivered may be about 5 percent, but the standard deviation of the amount applied to the field would be greater because of nonuniform leveling and intake capacities. Service companies can estimate the net amount of water applied by measuring the average soil water content prior to several normal irrigations and the average amount retained 2 to 3 days after these irrigations.

If rainfall is measured with at least one gage on each small farm and perhaps with several gages on large farms, the standard deviation of measured rainfall can be assumed to be $S_R = 3$ mm. If only widely scattered rain gages are used, S_R may be much greater.

If soil water depletion is to be monitored, the error due to drainage can be minimized if the monitoring is delayed 3 to 4 days after an irrigation. Drainage from the soil also varies with ET rates (Jensen, 1972, and Miller and Aarstad, 1974). The standard deviation of estimated upward flow into the root zone is relatively unknown.

Each estimated standard error in equation [2] should be divided by the number of samples or measurements used to determine the magnitude of the independent variable. The S_D will be reduced most by increasing the number of samples used for the variable with the largest standard error

$$(S_D = \sqrt{S_1^2/n_1 + \ldots + S_n^2/n_n}).$$

CONFIDENCE LEVELS

The expected confidence levels when scheduling irrigations using a climatic-based ET model and the influence of major components can best be illustrated with an example. The confidence limits of the projected irrigation dates in this example were approximated at the 95 percent probability level ($\pm 2\sigma$) as follows:

$$\text{C.L.} = \frac{2\,S_D}{[\text{ET}]} \quad \ldots\ldots\ldots\ldots \quad [3]$$

where C.L. is the approximate confidence limit in days, S_D is the estimated standard error of soil water depletion, and [ET] is the expected mean ET rate from the date of computation to the next forecasted irrigation.

Given:

Location: Kimberly, ID 42° N, elev. = 1195 m
Crop: Alfalfa, last cut on 10 June, expected next cutting 4 August (irrigation not permitted 28 July - 11 August).
Last irrigation: 20 June
Last monitored: 30 June, 4 neutron probe sites, D = 105 mm
Last update and forecast: 5 July, estimated D = 145 mm
Available soil water: Maximum = 300 mm
Allowable depletion = 0.65 x 300 = 195 mm
Average ET = 9 mm/day
Rainfall = 0 (average July rainfall is 6 mm)

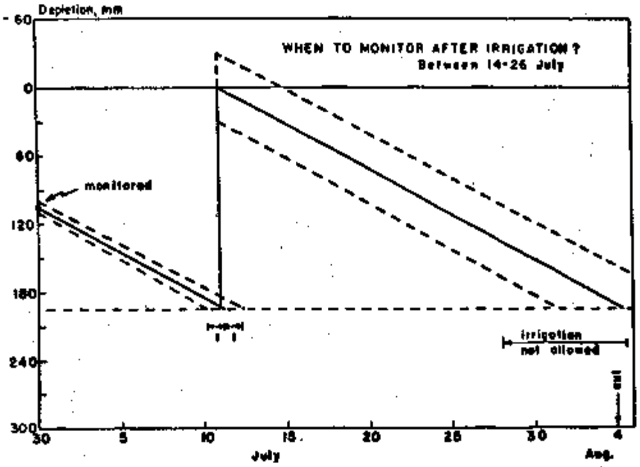

FIG. 4 Example confidence limits at the 95 percent probability level associated with irrigation scheduling after monitoring on 30 June.

Results

With a scheduling model using daily ET estimates, the projected first irrigation date of 11 July has confidence limits of ± 1 day. If a full irrigation is applied on 11 July as forecasted and the estimated standard deviation for $S_{(I-d)}$ is 15 mm, the confidence limits increase greatly after irrigating because of the large uncertainty of the irrigation depth. Also, the large uncertainty due to $S_{(I-d)}$ masks the smaller uncertainty of the monitored soil water depletion until the field can be monitored again. The constraint of not allowing an irrigation for 1 wk before the intended next harvest date until 1 wk after harvest is very common. Therefore, the irrigation service groups would monitor this field no sooner than 3 days after the 11 July irrigation to minimize the error due to drainage, and no later than 26 July to determine whether another irrigation should be recommended before the August cutting. In this example, if the soil water depletion on the date of monitoring was near the minimum depletion, or the upper confidence limit, an irrigation might not be needed until after the August cutting. If the soil water content was near the maximum depletion, or the lower limit, then the service company might recommend at least a partial irrigation before cutting.

In many irrigated areas with limited water supplies or with high water costs, full irrigations commonly are not applied after midseason. This practice allows the soil water to be depleted so that over-winter precipitation can be retained, but more frequent monitoring may be required, because there will be less water available for crop use following an irrigation.

In areas where expected rainfall is significant, the confidence limits associated with expected rainfall should be included in determining the confidence limits of the forecast irrigation dates.

The example illustrated in Fig. 4 reveals several points. Soil water depletion may be monitored on this crop and soil only once each 3 to 4 wks if the service company knows the approximate amount of irrigation water applied and rainfall is either measured or negligible. It also illustrates that a large uncertainty of a single component affecting soil water depletion will mask or dominate the overall uncertainty of estimated soil water depletion and projected irrigation dates.

The effect of using a model to estimate daily ET

TABLE 2. COMPARISON OF THE CONFIDENCE LIMITS ASSOCIATED WITH THE STANDARD ERROR OF DAILY ET ESTIMATES ($S_{y.x}$) WITH CONFIDENCE LIMITS ASSOCIATED WITH THE STANDARD DEVIATION OF EXPECTED ET ($S_{\overline{et}}$) AT KIMBERLY, IDAHO.

Date	Action	Confidence limit based on $S_{y.x}$	Confidence limit based on $S_{\overline{et}}$	Difference
		days		
30 June	Soil water depletion (D) measured	0.6	0.6	0
11 July	Projected date of irrigation	1.0	2.1	-1.1
11 July	Estimated D after irrigating	3.9	4.3	-0.4
20 July	Estimated D = 72 mm	3.9	5.2	-1.3
25 July	Before monitoring D	4.0	5.8	-1.8
25 July	After measuring D	0.6	0.6	0

on the confidence limits compared with using expected ET rates for the area is summarized in Table 2 for the example. These data show that the large increase in confidence limits caused by the irrigation persisted until the next monitoring date. Also, the model using daily ET estimates reduced the confidence limits by 0.4 to 1.8 days compared with the model using expected or mean ET rates for this crop and area.

The confidence limits illustrated in Fig. 4 and Table 2 are approximately at the 95 percent probability level. For most farm crops on medium textured soils reserve available soil water probably is sufficient to operate within confidence limits expected at the 68 percent probability level or ± 1 estimated standard deviation.

SUMMARY AND CONCLUSIONS

Irrigation scheduling services using computers and models that simulate plant growth and daily ET are rapidly expanding in the western USA. Estimates of soil water depletion and projected irrigation dates for individual fields are usually verified by periodically monitoring each field with gravimetric soil sampling techniques, neutron probes, or the "feel" method. Irrigation scheduling service groups using models to estimate daily ET may reduce the confidence limits at the 95 percent probability level 0.5 to 2 days depending on the period of time involved compared with projections based on expected or average ET data for a given crop, stage of growth, and region. The confidence limits of forecasted irrigation dates are dominated by the component having the greatest uncertainty. For most surface-irrigated farms, the greatest uncertainty is associated with the quantity of water applied during an irrigation, except when excessive water has been applied or when a heavy rain decreases soil water depletion to zero.

The estimated standard deviation of daily evapotranspiration varies from 0.9 to 1.3 mm/day in the western USA. The estimated standard deviation decreases to about 0.5 to 0.7 mm/day for 15-day periods or longer. The estimated standard error ($S_{y.x}$) for estimated daily ET using ET models that require daily climatic data is about 1 mm/day. $S_{y.x}$ decreases inversely with the square root of time for periods of 1 to about 40 days. Therefore, ET models do not reduce the standard errors of daily estimates significantly, but reduce $S_{y.x}$ to about one-half the estimated standard deviation of mean ET for summer months. The standard error in estimating daily evapotranspiration is normally distributed.

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